Journal of the Association for Information Systems

JAIS

Research Perspective

Design Science in Decision Support Systems Research: An Assessment using the Hevner, March, Park, and Ram Guidelines

David Arnott
Monash University
david.arnott@monash.edu

Graham Pervan
Curtin University
graham.pervan@cbs.curtin.edu.au

Abstract

Design science has been an important strategy in decision support systems (DSS) research since the field's inception in the early 1970s. Recent reviews of DSS research have indicated a need to improve its quality and relevance. DSS design-science research has an important role in this improvement because design-science research can engage industry and the profession in intellectually important projects. The Hevner, March, Park, and Ram's (HMPR) guidelines for the conduct and assessment of information systems design-science research, published in MIS Quarterly in 2004, provides a vehicle for assessing DSS design-science research. This paper presents research that used bibliometric content analysis to apply the HMPR guidelines to a representative sample of 362 DSS design-science research papers in 14 journals. The analysis highlights major issues in DSS research that need attention: research design, evaluation, relevance, strategic focus, and theorizing.

Keywords: *Decision Support Systems, Group Support Systems, Executive Information Systems, Data Warehousing, Business Intelligence, Design Science, Review.*

* Juhani Iivari was the accepting senior editor. This article was submitted on 17th May 2011 and went through two revisions.

Volume 13, Issue 11, pp. 923-949, November 2012

Design Science in Decision Support Systems Research: An Assessment using the Hevner, March, Park, and Ram Guidelines

1. Introduction

Design-science research (DSR) is an alternative, or complement, to the natural-behavioral science approach that is dominant in information systems research. In design-science research, the researcher "creates and evaluates IT artifacts intended to solve identified organisational problems" (Hevner, March, Park, & Ram, 2004, p. 77). It involves the creation of innovative IT artifacts – artifacts that address unsolved problems or significantly affect IT practice. March and Smith (1995) clearly draw a distinction between natural-behavioral and design-science research: "Whereas natural science tries to understand reality, design science attempts to create things that serve human purposes" (p. 253). Design-science research is particularly relevant for contemporary information systems (IS) because it helps researchers confront two of the major challenges of the discipline: the role of the IT artifact in IS research (Orlikowski & Iacono, 2001) and the low level of professional relevance of many IS studies (Benbasat & Zmud, 1999). The terminology "design science" has gained momentum in IS since Nunamaker, Chen, and Purdin (1990-91) suggested systems development as a research method, and Walls, Widmeyer, and El Sawy (1992) defined design theory in IS reseach. March and Smith (1995) was the first actual use of the design science term in IS, but the landmark publication is Hevner et al. (2004), which proposed a set of seven guidelines to assess design-science research in IS. In IS research, the design-science researcher "creates and evaluates IT artifacts intended to solve identified organisational problems" (Hevner et al., 2004, p.77). An important issue is the difference between high-quality professional design and design-science research. Design-science research should also address intellectually important topics, and this importance is associated with intellectual risk. Ideally, design-science research should produce important and interesting contributions to both IS theory and practice. An important differentiator between design-science research and design practice is that a research artifact should embody a significant amount of innovation or novelty. As Hevner et al. (2004, p 87) state: "The ultimate assessment for any research is 'What are the new and interesting contributions?'".

Decision support systems (DSS) is the area of the IS discipline that is focused on systems that support and improve managerial decision-making (Arnott & Pervan, 2005). Over the nearly four decades of its history, DSS has changed from a radical movement that changed the way information systems were perceived in business to a mainstream commercial IT movement that all organizations engage with. During this time, DSS has continued to be a significant sub-field of IS scholarship. DSS research has a long history of using design-science research strategies, and many of the early DSS projects involved designing and implementing innovative IT-based systems (for example, Meador & Ness, 1974; Keen & Gambino, 1983). One indicator of the success of this track record is that Hevner et al. (2004), in identifying and describing three exemplars of design science in IS research, selected two DSS articles. However, despite this tradition of success, recent reviews of DSS research have pointed to a need to increase the rigor of DSS design-science research (Arnott & Pervan, 2005, 2008; Eom, 2007).

This paper uses the Hevner et al. (2004) DSR guidelines to analyze relevant DSS research. One way to improve the quality of DSS design-science research, and to improve its contribution to general IS research, is to systematically review published projects and identify strategies for improvement. With the increase of interest in design science in IS, researchers seek guidance in the design and execution of their design-science research projects. Because of its long history with design science, insights from an analysis of DSS research may be of considerable assistance to the parent field. The paper is structured as follows: In Section 2, we overview the DSS academic area. In Section 3, we describe the literature analysis method and design and identify the DSS design-science research sample. In Section 4, we analyze the published design-science research in DSS in detail using the guidelines proposed by Hevner et al. (2004), the "HMPR guidelines". In Section 5, we suggest various strategies for improving DSS design-science research. Finally, in Section 6, we conclude.

2. The Decision Support Systems Field

As mentioned in the introduction, DSS is the area of the IS discipline that is focused on systems that support and improve managerial decision-making. While the overwhelming majority of DSS articles clearly address management support and some authors even call the field "management support systems", it is difficult to distinguish between managerial decision-making and the strategic decision-making of senior professionals such as legislators, economists, and medical specialists. The work of these senior professionals is "managerial" without the managerial label. Accordingly, DSS that support senior professionals are included in this study. There is also considerable overlap between DSS and operations research/management science. The distinguishing feature of DSS that helps define the area is its focus on the development and use of IT-based systems; that is, the "systems" of DSS. The "support" of DSS is also significant in the field's culture and definition; that is, DSS should support decision-making, not replace the person in the decision-making process. DSS has been an important area of IS scholarship since it emerged in the 1970s. It has also been a major area of IT practice and the decisions made using IT-based decision support can have a significant effect on the nature and performance of an organization.

There are various DSS taxonomies, which include the seminal framework of Gorry and Scott Morton (1971). In the nearly four decades since the Gorry and Scott Morton paper, a number of distinct DSS sub-fields have emerged in research and practice. Power (2008) developed a framework based on "the dominant technology component or driver of the decision support system". He identified five generic DSS types: data-driven DSS, model-driven DSS, knowledge-driven DSS, document-driven DSS, and communications-driven DSS. Clark, Jones, and Armstrong (2007), in an investigation of the dynamic nature of management support systems, used a four-type taxonomy of management support: decision support systems, executive information systems (EISs), knowledge management systems (KMSs), and business intelligence (BI). The DSS taxonomy adopted for this paper is that developed by Arnott and Pervan (2008) in their analysis of general DSS research. Their taxonomy has aspects of both the Power (2008) and Clark et al. (2007) frameworks. Arnott and Pervan identified seven DSS types that are separated by technology, theory foundations, user populations, and decision tasks. These seven types are:

- Personal decision support systems (PDSS), which are usually small-scale systems that are developed for one manager, or a small number of independent managers, to support a decision task. Perhaps the oldest DSS type, PDSS, remains important in practice, especially in the form of user-built models and data analysis systems (Arnott, 2008).

- Group support systems (GSSs), which "consist of a set of software, hardware, and language components and procedures that support a group of people engaged in a decision-related meeting" (Huber, 1984). GSSs are typically implemented as electronic meeting systems (EMSs) (Dennis, George, Jessup, Nunamaker, & Vogel, 1988) or group decision systems (GDSs) (Pervan & Atkinson, 1995).

- Negotiation support systems (NSSs), which are DSS that operate in a group context but that, as the name suggests, involve the application of IT to facilitate negotiations (Rangaswamy & Shell, 1997). As the group members in NSSs are opposing parties, NSSs have had to be developed on a different theory foundation to that of GSSs.

- Intelligent decision support systems (IDSS), which involve the application of artificial intelligence techniques to decision support. IDSS can be classed into two generations: the first involved the use of rule-based expert systems for decision support, and the second uses neural networks, genetic algorithms, and fuzzy logic (Turban, Aronson, & Liang, 2005).

- Knowledge management-based DSS (KMDSS), which are systems that support decision making by aiding knowledge storage, retrieval, transfer, and application. KMDSS can support individual and organizational memory, and inter-group knowledge access (Burstein & Carlsson, 2008).

- Data warehousing (DW), which provides the large-scale data infrastructure for decision support. In general terms, a data warehouse is a set of databases created to provide information to decision makers (Cooper, Watson, Wixom, & Goodhue, 2000). In practice, data warehousing includes enterprise data warehouses, data marts, and applications that extract, transform, and load (ETL) data into the data warehouse or mart (Watson, 2001).

- Enterprise reporting and analysis systems (ERASs), which are enterprise-scale systems that include executive information systems (EISs), online analytical processing systems (OLAP), corporate performance management systems (CPM), business intelligence (BI), and, more recently, business analytics (BA). BI tools access and analyze data warehouse information using predefined reporting software, query tools, and analysis tools (Nelson, Todd, & Wixom, 2005).

While PDSS still provide significant decision support in organizations, current IT professional interest in decision support is overwhelmingly focussed on BI and DW. The annual Gartner EXP CIO surveys have consistently found that BI is a major technology priority for CIOs (Gartner, 2007, 2008, 2009, 2010). In a more specific report, Graham, Biscotti, and Horiuchi (2006) predicted that the business intelligence platform market would witness a compound annual growth of 6.5 percent over the next five years.

3. Research Method and Design

3.1. General Approach

To investigate the nature of design-science research in the DSS field, we analyzed relevant published research. There are two fundamental strategies for literature analysis. The first, thematic analysis, involves classifying and analysing articles according to themes that are relevant to the theory and practice goals of a research project (Webster & Watson, 2002). Thematic analysis is by far the most common form of literature review in journal articles and doctoral theses. The second fundamental strategy is bibliometrics, which involves the measurement of publication patterns. The two most common bibliometric methods are citation analysis (Osareh, 1996) and content analysis (Weber, 1990). Content analysis involves the coding and analysis of a representative sample of research articles. In this approach, data capture is driven by a protocol that can have both quantitative and qualitative aspects. This form of data capture is labour intensive but has the advantage that it can illuminate the deep structure of the field in a way that is impossible to achieve with other literature analysis approaches.

In general IS research, content analysis has been used by Alavi and Carlson (1992) in their analysis of management information system's intellectual evolution, by Farhoomand and Dury (1999) in what they termed an "historiographical" examination of IS research, and by Chen and Hirschheim (2004) in their paradigmatic and methodological examination of IS research from 1991 to 2001. In specific segments of IS research, Guo and Sheffield (2008) used content analysis to examine knowledge management research, while Palvia, Pinjani, and Sibley (2007) analyzed all articles published in Information & Management. In DSS literature analysis, Arnott and Pervan (2005, 2008) used content analysis in overall reviews of the field, while Benbasat and Nault (1990) used content analysis to critically assess empirical DSS research. Fjermestad and Hiltz followed this approach to analyze group support systems research both in the laboratory (Fjermestad & Hiltz, 1998/1999) and in the field (Fjermestad & Hiltz, 2000/2001). Pervan (1998) used content analysis in a general review of GSSs research. Following this tradition, the research in this paper adopted a content-analysis method to help understand the nature of DSS design-science research and to assess its strengths and weaknesses.

3.2. Timeframe

The time period of published research that we chose for this project is 1990 to 2005. The start of this analysis period is marked by two much cited reviews: Eom and Lee (1990) and Benbasat and Nault (1990). Both of these reviews cover the DSS field from its inception to the late 1980’s. A third review paper that focuses on DSS implementation, Alavi and Joachimsthaler (1992), provides a further anchor for the starting date of our analysis, as does the TIMS/ORSA and National Science Foundation sponsored discipline assessment (Stohr & Konsynski, 1992). The period 1990 to 2005 also marks an interesting period in industry with the deployment of several new generations of DSS, especially the large-scale approaches of EIS, data warehousing, and business intelligence. During the same period, the IS discipline witnessed a significant growth in the use of non-positivist research methods (Walsham, 1995). To help identify trends in DSS research, we divided the sample into four four-year eras: 1990-1993, 1994-1997, 1998-2001, and 2002-2005.

3.3. The Selection of Journals

The sample for the project comprises DSS research articles published between 1990 and 2005 in the 14 journals shown in Table 1. We adopted a large set of quality journals as a basis of the sample because we believe that this best represents the invisible college of DSS research. Previous analyses of information systems research have used a similar sampling approach (Alavi & Carlson, 1992; Benbasat & Nault, 1990; Chen & Hirschheim, 2004; Pervan, 1998). Alavi and Carlson (1992) used eight North American journals for their sample. However, Webster and Watson (2002) have criticized the overemphasis on North American journals in review articles. In response, we included five European information systems journals (*ISJ, EJIS, I&O, JIT*, and *JSIS*) in our sample. Following Chen and Hirschheim (2004), the classification of a journal as US or European is largely based on the location of the publisher. Galliers and Meadows (2003) used a similar approach: they made their journal-origin decision on the basis of the location of the publisher and the nationality of the editor. Analyses of IS publishing have found significant differences between the nature of research published in North American and European journals (Cavaye, 1996; Galliers & Meadows, 2003; Hirschheim, 1992).

3.4. The Article Sample and Procedure

To arrive at the DSS design-science research sample, we first selected the journal sample . We electronically selected DSS articles in 14 journals by examining key words and titles. We performed a manual check of the table of contents of each issue of each journal. In addition, we examined the text of each potential article for analysis to verify its decision support content in terms of the definition of DSS provided above. This procedure identified 1,167 DSS articles. Table 1 shows the distribution of the DSS articles in the sample by journal. Overall, 15.1 percent of published articles in the 14 journals between 1990 and 2005 were in the DSS field. When only the general IS journals in the sample are examined, the proportion of DSS articles increases to 18.9 percent. Each of these measures indicate that DSS is an important part of the IS discipline. This means that the findings of the literature analysis may also illuminate the nature of general IS design science.

Table 1. DSS and DSS Design-Science Research Article Samples by Journal

Journal	Origin	2009 ISI impact factor	Journal orientation	No of DSS articles published	DSS DSR articles published	DSS DSR articles as a percentage of published DSS articles
Decision Sciences (DS)	US	2.380	Multi-discipline	67	19	28.4
Decision Support Systems (DSS)	US	2.622	General IS	500	247	49.4
European Journal of Information Systems (EJIS)	Europe	1.200	General IS	25	5	20.0
Group Decision and Negotiation (GD&N)	US	0.783	Specialist IS	139	24	17.3
Information and Management (I&M)	US	2.282	General IS	104	13	12.5
Information and Organization (I&O)	Europe	Not abstracted	General IS	16	1	6.3
Information Systems Journal (ISJ)	Europe	1.419	General IS	16	1	6.3
Information Systems Research (ISR)	US	1.792	General IS	34	5	14.7
Journal of Information Technology (JIT)	Europe	2.049	General IS	25	2	8.0
Journal of Management Information Systems (JMIS)	US	2.098	General IS	84	18	21.4
Journal of Organizational Computing and Electronic Commerce (JOC&EC)	US	0.552	Specialist IS	73	12	16.4
Journal of Strategic Information Systems (JSIS)	Europe	2.212	General IS	8	1	12.5
Management Science (MS)	US	2.227	Multi-discipline	41	13	31.7
MIS Quarterly (MISQ)	US	4.485	General IS	35	1	2.9
Total				1,167	362	31.0

We coded each of the 1,167 articles using the Alavi and Carlson (1992) taxonomy as modified by Pervan (1998) to include action research and to distinguish between positivist and interpretive case studies. Table 2 shows the result of this coding. Both researches inspected the articles from the article types “tools”, “techniques”, “methods”, “model applications”, “conceptual frameworks and their application”, “description of type or class of product”; “technology, systems, etc”, “description of specific application”, “system, etc”, and “action research”, to determine whether they met Hevner et al.’s (2004) design-science research definition. In particular, we inspected each paper for a focus on an innovative artifact instead of providing a description of an existing commercial product. This yielded a DSS design-science research sample of 362 articles. A list of the articles in the sample is available at http:dsslab.infotech.monash.edu.au/index.php/projects/dss-foundations. This sample shows the importance of design-science research because it is the primary strategy of 31 percent of DSS articles.

Table 2. The DSS and DSS Design-Science Research Samples by Article Type

Article type			All DSS articles No.	All DSS articles Percent of DSS sample	DSR articles No.	DSR articles Percent of DSR sample
Non-empirical	Conceptual	DSS frameworks	53	4.5	0	0.0
		Conceptual models	30	2.6	0	0.0
		Conceptual Overview	49	4.2	0	0.0
		Theory	22	1.9	0	0.0
	Illustrative	Opinion and example	22	1.9	0	0.0
		Opinion and personal experience	5	0.4	0	0.0
		Tools, techniques, methods, model applications	148	12.7	92	25.4
	Applied concepts	Conceptual frameworks and their application	69	5.9	41	11.3
Empirical	Objects	Description of type or class of product, technology, systems etc.	39	3.3	27	7.5
		Description of specific application, system etc.	215	18.4	199	55.0
	Events/ processes	Lab experiment	209	17.9	0	0.0
		Field experiment	19	1.6	0	0.0
		Field study	37	3.2	0	0.0
		Positivist case study	64	5.5	0	0.0
		Interpretivist case study	37	3.2	0	0.0
		Action research	6	0.5	3	0.8
		Survey	77	6.6	0	0.0
		Development of DSS instrument	4	0.3	0	0.0
		Secondary data	28	2.4	0	0.0
		Simulation	34	2.9	0	0.0
Total			1,167		362	

The design science articles in the sample covered the whole range of DSS types. The sample was dominated by personal DSS (47.2 percent), intelligent DSS (26 percent), and group support systems (14.1 percent), while there were relatively few of enterprise reporting and analysis systems (3.6 percent), negotiation support systems (3.3 percent), knowledge management systems (1.9 percent), and data warehousing (1.1 percent). The remaining articles (2.8 percent) addressed multiple types of DSS. We coded the 362 DSS design-science research articles using the protocol that Appendix A shows. We based the protocol on the guidelines proposed by Hevner et al. (2004). The time taken to code each article varied from 20 minutes to over one hour. To ensure coding validity, both researchers coded each paper, with disagreements in coding discussed and resolved. This approach has been used in prior studies (e.g., Eierman, Niederman, & Adams, 1995). It was important to keep re-reading Hevner et al. (2004) during the coding process in order to remain calibrated to their definitions, implied constructs, and meanings. An important aspect of coding validity is that the two researchers have decades of experience in the DSS area, are experienced journal reviewers and editors, and have published DSS design-science research projects.

4. An Analysis of Design Science in DSS Research

In this section, we present the analysis of the DSS design-science research sample using a systematic application of the guidelines proposed by Hevner et al. (2004). Table 3 shows these "HMPR guidelines" (taken from Hevner et al., 2004, p. 83).

Table 3. The HMPR Design-Science Research Guidelines	
1. Design as an artifact	Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation.
2. Problem relevance	The objective of design-science research is to develop technology-based solutions to important and relevant business problems.
3. Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods.
4. Research contributions	Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies.
5. Research rigor	Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact.
6. Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment.
7. Communication of research	Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences.

We systematically identified high-quality articles through the computation of the "design science balanced scorecard index" by averaging the quality assessments using the HMPR guidelines for each paper. This index, when sorted from best to worst, revealed several excellent articles that scored highly across most guidelines. These high-quality articles are used to highlight our analysis in the following sections.

4.1. HMPR Guideline 1 – The Design Artifact

The first HMPR guideline concerns the design artifact. Hevner et al. (2004, p. 83), following the definitions of March and Smith (1995), state: "Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation". Hevener et al. define four classes of IT design artifacts:

- Constructs – concepts that form the research domain's vocabulary
- Models – a set of propositions or statements expressing relationships among constructs
- Methods – a set of steps used to perform a task, and
- Instantiations – realized information systems.

This taxonomy has been widely used in IS design-science research articles including Hevner et al. (2004). The coding of the DSS sample yielded 396 artifacts. Most articles focused on one artifact, their "primary" artifact. Thirty-four articles identified significant secondary artifacts in addition to their primary artifacts. No paper explicitly discussed three significant artifacts. This pattern of reporting artifacts may be a result of the nature of journal publishing. The word count limits on printed journal articles could cause authors to focus their writing on a primary artifact and omit any mention of other artifacts. Table 4 shows the results of the coding.

Table 4. Design Artifacts in DSS Design-Science Research										
Design artifact	**1990-1993**		**1994-1997**		**1998-2001**		**2002-2005**		**Total**	
	No.	%	No.	%	No.	%	No.	%	No.	%
Construct	0	0.0	0	0.0	1	1.2	1	0.9	2	0.5
Model	7	9.3	9	7.1	5	5.9	7	6.4	28	7.1
Method	12	16.0	34	27.0	18	21.2	39	35.5	103	26.0
Instantiation	56	74.7	83	65.9	61	71.8	63	57.3	263	66.4
Total	75		126		85		110		396	

Clearly, the focus in the reporting of DSS research over all time periods has been on instantiations; they constitute close to two-thirds of all reported artifacts. High-quality examples of these instantiation artifacts include R-EIS, a repository-based executive information system (Chen, 1995), and PUZZLE, a strategic business intelligence system (Rouibah & Ould-Ali, 2002). The development of methods has increased to 35.5 percent of design artifacts in the most recent time period. An example of a high-quality method artifact in this period is a multi-agent design for a DSS (Hall, Guo, Davis, & Cegielski, 2005).

The artifact taxonomy of March and Smith (1995), as used in this HMPR guideline, has an implied linear hierarchy, at least from constructs through models to methods. Instantiations occupy the peak of the hierarchy, but the linearity is less clear. As Hevner et al. (2004) state: "Instantiations show that constructs, models, or methods can be implemented in a working system" (p. 79). March and Smith (1995) suggest that the direction of development may not be hierarchical "[because] an instantiation may actually precede the complete articulation of its underlying constructs, models, and methods" (p. 258). Nevertheless, one interpretation of Table 4 is that DSS design-science artifacts lie in some form of a Guttman scale (Neuman, 2003). This means that the reported instantiations in Table 4 embody a method, model, or construct, and that the reported method artifacts in Table 4 embody a model or construct. In the sample, this embodiment is most likely to be implicit. Supporting this interpretation is the fact that around 80 percent of the reported secondary artifacts were lower in the March and Smith taxonomy than their primary artifact. In one sense, the dominance in the sample of instantiations as artifacts is a positive sign for the DSS field. It shows that design ideas have been implemented in some way and do not exist as abstract entities.

4.2. HMPR Guideline 2 – Problem Relevance

The second HMPR guideline addresses problem relevance. Hevner et al. (2004, p. 83), define the second guideline by saying that: "The objective of design-science research is to develop technology-based solutions to important and relevant business problems". Unfortunately, Hevner et al. provide no guidance on how to assess or categorize the "importance" and "relevance" constructs.

To operationalize "importance" in this project, we used Anthony's well-accepted concept of a hierarchy of management processes and activities (Anthony, 1965). This framework divides management activities into a hierarchy of importance to the organization from the strategic to the tactical and operational. Table 5 presents the primary focus of the DSS articles over time using Anthony's management activities. The Table reveals that the focus has varied a little over time and has been mostly at the operational level (75.7 percent). Overall, only 10.5 percent of articles involved artifacts that had a strategic focus or impact.

Table 5. The Importance of Business Problems in DSS Design-Science Research

	1990-1993		1994-1997		1998-2001		2002-2005		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Strategic	3	4.2	12	10.4	14	18.2	9	9.2	38	10.5
Tactical	14	19.4	15	13.0	10	13.0	11	11.2	50	13.8
Operational	55	76.4	88	76.5	53	68.8	78	79.6	274	75.7
Total	72		115		77		98		362	
Strategic	3	4.2	12	10.4	14	18.2	9	9.2	38	10.5

Further analysis of importance across DSS types revealed that the operational focus was consistently high across personal DSS, GSSs, ERASs, IDSS, and NSSs. In contrast, however, KMSs were mostly tactical (71.4 percent). An example of design-science research with a tactical impact is KNOVA, a knowledge-based DSS for radiologists (Holden & Wilhelmij, 1995/1996). In concert with the general sample, few KMS were focused on the strategic level. A high-quality exception is an IDSS for strategic alignment in manufacturing (Kathuria, Anandarajan, & Igbaria, 1999).

We assessed the relevance of DSS design-science research with respect to two main target audiences: IS practitioners and managerial users. An overarching factor in assessing research relevance was whether it involved a new and interesting contribution. We coded the relevance of each paper on a scale of high, medium, and low. In coding relevance, we erred on the generous side; that is, when a decision between categories was difficult, we coded the paper in the higher category of relevance. The researchers have had significant senior IS professional experience. This includes DSS development and consulting, and IT management and governance. The researchers have also had significant senior management experience including divisional management and executive positions. They are experienced DSS researchers who have published in leading journals and are experienced with all of the methods involved in the article sample. In coding relevance, we considered the extent that a manager would be able to use the research in their work or the work of their organization, the extent that an IS professional could use the research in their work, and the extent that they would be likely to promote the research to a colleague. As key element of assessing the “likely extent of use” is the novelty of the research contribution. Tables 6 and 7 show the result of the coding.

Table 6. The Relevance of DSS Design-Science Research to IS Practitioners

	1990-1993		1994-1997		1998-2001		2002-2005		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	3	4.2	5	4.3	2	2.6	5	5.1	15	4.1
Medium	19	26.4	29	25.2	28	36.4	26	26.5	102	28.2
Low	50	69.4	81	70.4	47	61.0	67	68.4	245	67.7
Total	72		115		77		98		362	

Table 7. The Relevance of DSS Design-Science Research to Managerial Users

	1990-1993		1994-1997		1998-2001		2002-2005		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	14	19.4	28	24.3	21	27.3	23	23.5	86	23.8
Medium	24	33.3	33	28.7	30	39.0	39	39.8	126	34.8
Low	34	47.2	54	47.0	26	33.8	36	36.7	150	41.4
Total	72		115		77		98		362	

The relevance of DSS design-science research to its two main target audiences, IS practitioners and managerial users, has been relatively stable over time. IS practitioner relevance was mostly low in the first period (69.4 percent in the low relevance category) and has remained that way. Few articles (4.1 percent overall) were rated of high relevance to IS practitioners. These included R-EIS, a repository-based EIS (Chen, 1995), a DSS for strategic product development (Kettelhut, 1991), and TOP-Modeler, a modelling tool that supports organizational design in manufacturing firms. The story for managerial users is a little better with 23.8 percent of the articles rated high in managerial relevance and only 41.4 percent of low relevance. The levels of managerial relevance have also been quite stable over time. Examples of high managerial relevance included R-EIS (Chen, 1995), a neural-net based DSS for financial forecasting (Walczak, 2001), and a DSS for water restriction policies (Reico, Ibanez, Rubio, & Criado, 2005). A further cross-tabulation of IS practitioner relevance against managerial user relevance reveals only nine of the 362 articles were relevant to both groups; the repository-based EIS, R-EIS, was one such example (Chen, 1995).

A further analysis of IS practitioner relevance over the different DSS types showed better relevance ratings for ERAS (53.8 percent of low relevance), DW systems (25 percent low), and KMS (28.6 percent low), although it should be noted that the number of articles of these types is quite small. A similar analysis of managerial user relevance revealed that articles on ERASs, KMSs, and NSSs were of greater relevance to these managerial users than other DSS.

4.3. HMPR Guideline 3 – Design Evaluation

The third HMPR guideline concerns the evaluation of the design artifacts. Hevner et al. (2004, p. 83), define this guideline as “The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods”. The coding of the DSS design-science research articles for this guideline was based on the evaluation taxonomy presented by Hevner et al. (2004, p. 86). Table 8 shows the result of this coding.

Table 8. Evaluation Methods in DSS Design-Science Research

		1990-1993		**1994-1997**		**1998-2001**		**2002-2005**		**Total**	
										No.	%
Observational	Case study	6	8.3	10	8.7	13	16.9	13	13.3	42	11.6
	Field study	1	1.4	0	0.0	3	3.9	3	3.1	7	1.9
Analytical	Static	0	0.0	0	0.0	1	1.3	0	0.0	1	0.3
	Architecture	0	0.0	1	0.9	0	0.0	0	0.0	1	0.3
	Optimization	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	Dynamic	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Experimental	Controlled experiment	1	1.4	4	3.5	5	6.5	5	5.1	15	4.1
	Simulation	14	19.4	17	14.8	17	22.1	26	26.5	74	20.4
Testing	Functional	0	0.0	2	1.7	0		2	2.0	4	1.1
	Structural	0	0.0	0	0.0	0		1	1.0	1	0.3
Descriptive	Informed argument	0	0.0	3	2.6	2	2.6	2	2.0	7	1.9
	Scenarios	13	18.1	21	18.3	8	10.4	15	15.3	57	15.7
None		37	51.4	57	49.6	28	36.4	31	31.6	153	42.3

Surprisingly, overall, 42.3 percent of articles were coded as “none”. This means that the focus of the paper was the presentation and description of an artifact without any attempt of establishing its worth, effectiveness, or usefulness. This large proportion of un-evaluated projects is a major problem for DSS design-science research. Over time, the situation improved from 51.4 percent coded as "none" in the first period to 31.6 percent in the most recent period. However, 31.6 percent "none" is still a poor result for the field. A further analysis of evaluation method against DSS type revealed that "none" was coded noticeably more often for GSSs (54.9 percent) but less often for IDSS (29.8 percent).

One possible reason for the lack of artifact evaluation in the sample could be found in the nature of the DSS field. Although DSS has a predominantly IS orientation, it also has roots in management science and computer science. These fields are typified by published articles that report innovative artifacts without explicit evaluation. If some editors and reviewers have a computer science or management science orientation, it could account for many of the unevaluated articles in the sample.

Of the articles that did include an evaluation of the artifact, three approaches dominate: simulation at 20.4 percent of the sample, scenarios at 15.7 percent, and case study at 11.6 percent, with another approach, controlled experiment, significant at 4.1 percent. One of the controlled experiments was conducted in the field and the remaining 14 in the laboratory. The other evaluation approaches identified by Hevner et al. (2004) are either hardly used, or not used at all. Interestingly, only 13.5 percent of articles evaluated their artifacts in the field. We further analysed the evaluation method by DSS type was performed but was limited to studies where an evaluation was actually undertaken. This analysis showed that:

- PDSS (171 articles, 47.2 percent of the sample) were mostly evaluated by simulation (37.1 percent) (e.g., Hall et al., 2005), scenarios (28.9%) (e.g., Balbo & Pinson, 2005), and case studies (18.6 percent) (e.g., Tavana & Banerjee, 1995)

- GSSs (51 articles, 14.1% of the sample) were mostly evaluated by case studies (34.8 percent) (e.g., de Vreede & Dickson, 2003; Dennis, Carte, & Kelly, 2003), controlled experiments (21.7 percent) (e.g., Zhang, Sun, & Chen, 2005), and scenarios (17.4 percent) (e.g., (Moreno-Jiminez, Joven, Pirla, & Lanuza, 2005)

- Among ERASs articles (13 articles, 3.6 percent of the sample), three from the eight evaluated used scenarios (e.g., Chen, 1995)

- For DW (four articles, 1.1% of the sample), only one study was evaluated and it used a case study (Sen & Sen, 2005)

- IDSS (94 articles, 26% of the sample) were mostly evaluated by simulation (50 percent) (e.g., Walczak, 2001) followed by scenarios (14.2 percent) (e.g., Katerattanakul & Han, 2003)

- For KMSs (seven articles, 1.9 percent of the sample), all four articles evaluated were by case studies (e.g., Holden & Wilhelmij, 1995/1996), and

- For NSSs (12 articles, 3.3 percent of the sample), the six articles evaluated were by scenarios (66.7 percent) (e.g., Kuula, 1998) or case studies (33.3 percent) (e.g., Noakes, Fang, Hipel, Kilgour, 2005).

The HMPR guideline three stresses rigor in evaluation via well-executed methods. Table 8 and the associated analysis by DSS type shows the presence or absence of evaluation, but not the quality of evaluation. To analyze the quality of evaluation, we first coded each paper that undertook some form of evaluation for the appropriateness of the evaluation method to the objects of the study and the nature of the artifact. Secondly, we assessed the quality of the evaluation method's execution in each paper on a scale of high, medium, and low. Like the coding strategy used for Tables 6 and 7, we generously assessed evaluation method choice and execution quality. Tables 9 and 10 contain these assessments for those DSS articles where an evaluation method was used.

Table 9. The Choice of Evaluation Method in DSS Design-Science Research										
	1990-1993		**1994-1997**		**1998-2001**		**2002-2005**		**Total**	
	No.	%	No.	%	No.	%	No.	%	No.	%
Highly appropriate	16	45.7	25	43.1	36	73.5	38	56.7	115	55.0
Adequate	18	51.4	32	55.2	12	24.5	28	41.8	90	43.1
Poor	1	2.9	1	1.7	1	2.0	1	1.5	4	1.9
Total	35		58		49		67		209	

In each era, when evaluation did occur, the level of appropriateness of the evaluation method choice was at least "adequate". This indicates that those researchers who evaluate design artifacts are making reasonable choices in terms of method. Over time, the quality of the choice of evaluation method has been a little variable, but there is no statistically significant trend in the coding. Of interest is that DSS researchers seldom choose to evaluate their artifacts in the field. Only 13.5 percent of articles in the sample and 23.4 percent of the articles that conducted evaluation were evaluated in the field.

Table 10 shows that in each era, when evaluation was conducted, the quality of evaluation was mostly medium to high. This indicates that those researchers are doing reasonably well in conducting the evaluation. Further, the proportion of low quality execution has steadily decreased from 37.1 percent in 1990-1993 to only 14.9 percent in 2002-2005.

Table 10. The Quality of Evaluation Execution in DSS Design Science Research										
	1990-1993		**1994-1997**		**1998-2001**		**2002-2005**		**Total**	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	5	14.3	16	27.6	13	26.5	23	34.3	57	27.3
Medium	17	48.6	24	41.4	26	53.1	34	50.7	101	48.3
Low	13	37.1	18	31.0	10	20.4	10	14.9	51	24.4
Total	35		58		49		67		209	

In summary, the overall picture in relation to evaluation is that, surprisingly, over 40 percent of DSS design-science research projects do not undertake explicit evaluation of the artifacts. When artifact evaluation is performed, researchers generally make an appropriate choice of method. Further, the quality of the execution of evaluation is steadily, and significantly, improving.

4.4. HMPR Guideline 4 – Research Contributions

The fourth HMPR guideline concerns the research contributions of design-science research. Hevner et al. (2004, p. 83), define this guideline by saying that "Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies". By design methodologies, Hevener et al. mean systems development methods and evaluation methods. In a similar manner to assessing problem relevance, an overarching factor was whether the research provided a new and interesting contribution. We examined each paper in the DSS sample for its primary research contribution according to the HMPR definition. We also recorded secondary research contributions where they occurred. Among the 362 articles, the design artifact was the primary research contribution in 360 cases, with only one paper having design foundations, and one having development and evaluation methods as their primary research contribution. Only eight articles had a significant secondary research contribution: one in the design artifact, six in design foundations, and one contribution to development and evaluation methods.

There were various examples of high-quality research contribution through a design artifact. These included a repository-based executive information system (Chen, 1995) and a strategic business intelligence system (Rouibah & Ould-Ali, 2002). Two notable contributions to design foundations were a design theory for systems that support emergent knowledge processes (Markus, Majchrzak, & Gasser, 2002), and a groupware-based business process re-engineering process (Dennis et al., 2003). An example of a high-quality contribution to evaluation methods is DeSanctis, Synder, and Poole (1994), who developed a method for conducting a preliminary evaluation of an EMS. In particular, their method assessed the match between user and designer perspectives on system interface, functionality, and holistic attributes.

4.5. HMPR Guideline 5 – Research Rigor

The fifth HMPR guideline concerns the rigor of design-science research. Hevner et al. (2004, p. 83), define this guideline by saying that "Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact". We operationalized this guideline using two constructs: the rigor of the theoretical foundations of the research, and the rigor of the research method. We coded each construct on a scale of strong, adequate, or weak. As with other HMPR guidelines, the coding was generous with respect to assessments at category boundaries. We coded the rigor of theory foundations by considering the use of appropriate foundation theory and, in particular, the argument as to why the foundation theory is appropriate. We coded the effective use of theory in artifact evaluation and the research discussion highly, which we also did with the consideration of the limitations or weaknesses of the theory foundations. Table 11 shows the result of the coding for the rigor of theory foundations. We coded over 80 percent of articles as either adequate or strong. This has been fairly consistent over time and represents a good result for the DSS field. A crosstabulation of the rigor of theory foundations with DSS type found that the data in Table 11 were fairly consistent across DSS type.

Table 11. The Rigor of the Theoretical Foundations of DSS Design-Science Research

	1990-1993		1994-1997		1998-2001		2002-2005		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Strong	20	27.8	41	35.7	26	33.8	38	38.8	125	34.5
Adequate	38	52.8	47	40.9	42	54.5	46	46.9	173	47.8
Weak	14	19.4	27	23.5	9	11.7	14	14.3	64	17.7
Total	72		115		77		98		362	

Table 12 shows the result of the coding of the rigor of research methodologies in the sample. The coding of research method considered whether the research question or problem was stated clearly, whether the research design (explicit or implicit) was appropriate to the question or problem, and whether the discussion of the results and findings was soundly based when data was collected and analyzed. Where there was no evaluation (i.e., no data was collected and analyzed), the rigor of research method was almost always coded as weak. The results are extremely disappointing, with 75 percent of articles in the weak category and only 3.3 percent coded as strong. Most of the articles in the "weak" set did not address research method and design at all. The time trend in the sample is for the less-rigorous category to decrease substantially over time, a positive result for the field. Unfortunately, the improvement has been in the adequate category rather than in the strong category.

Table 12. The Rigor of the Research Methodologies of DSS Design-Science Research

	1990-1993		1994-1997		1998-2001		2002-2005		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Strong	0	0.0	6	5.2	2	2.6	4	4.1	12	3.3
Adequate	10	13.9	21	18.3	18	23.4	31	31.6	80	22.1
Weak	62	86.1	88	76.5	57	74.0	63	64.3	270	74.6
Total	72		115		77		98		362	

For cases where evaluation did take place, Table 13 contains a crosstabulation of the rigor of the theoretical foundations against the rigor of the research methods. A Spearman's correlation of +0.48 reveals a significant association between the constructs and the table confirms the direction of the positive association. In the 21 design-science DSS cases where the theoretical foundations are weak, all 21 are weak in their research method (whereas the 125 articles with weak research method have a wide distribution of theoretical rigor). This may imply that DSS design-science researchers who are not rigorous with their theoretical foundations pay little attention to research method issues. However, the association only explains 23 percent of the variation and, as a result, predicting rigor of research method based on theoretical rigor may be problematic (note that, in Table 13, the rigor of research method is quite mixed for articles with strong or adequate theoretical rigor).

Table 13. Theoretical Foundations versus Research Methods

	Theoretical foundations							
Research methods	Strong		Adequate		Weak		Total	
	No.	%	No.	%	No.	%	No.	%
Strong	10	12.3	2	1.9	0	0.0	12	5.7
Adequate	45	55.6	27	25.2	0	0.0	72	34.4
Weak	26	32.1	78	72.9	21	100.0	125	59.8
Total	81		107		21		209	

4.6. HMPR Guideline 6 – Design as a Search Process

The sixth HMPR guideline concerns the iterative search process that is characteristic of high-quality design. Hevner et al. (2004, p. 83), define this guideline as "The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment".

Thirty-seven articles (10.2 percent of the sample) decomposed the design problem into sub-problems, 23 articles (6.4 percent of the sample) displayed iteration from the sub-problem solution to the overall problem solution, and 10 articles (2.8 percent of the sample) used satisficing to decide on the solution convergence point. This analysis shows little support for an evident means-ends search process in published DSS design-science research. However, by their nature, journal articles are written in a linear style. Often the research design and the project description can appear more ordered and more structured than was actually the case. It could be that the search process that should be part of quality design-science research is disguised by the journal publishing process.

One of the main differences between DSS and other types of IS is that there is rarely a "desired end" to a DSS project. At any point in time a DSS is an emergent artifact from an evolutionary process (Arnott, 2004); it may have a significantly different form over time. This aspect of DSS development can be acknowledged in the method section of design-science journal articles.

4.7. HMPR Guideline 7 – Communication of Research

The seventh and final HMPR guideline concerns the communication of research. Hevner et al. (2004, p. 83), define this guideline by saying that "Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences". The effectiveness of communication was coded on a scale of high, medium, and low, with the generous coding approach of other constructs. As mentioned above, both coders have significant technical and managerial experience. Table 14 and 15 show the coding results is. A possible bias in the coding of this guideline is assessing each paper for both technical and managerial communication. It could be that projects publish their results in multiple venues, some with a managerial focus and others with a technical focus.

Table 14. The Effectiveness of Technology-Oriented Communication in DSS Design Science										
	1990-1993		**1994-1997**		**1998-2001**		**2002-2005**		**Total**	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	17	23.6	29	25.2	28	36.4	41	41.8	115	31.8
Medium	43	59.7	61	53.0	41	53.2	48	49.0	193	53.3
Low	12	16.7	25	21.7	8	10.4	9	9.2	54	14.9
Total	72		115		77		98		362	

Table 15. The Effectiveness of Management-Oriented Communication in DSS Design Science										
	1990-1993		**1994-1997**		**1998-2001**		**2002-2005**		**Total**	
	No.	%	No.	%	No.	%	No.	%	No.	%
High	0	0.0	2	1.7	3	3.9	0	0.0	5	1.4
Medium	10	13.9	8	7.0	14	18.2	16	16.3	48	13.3
Low	62	86.1	105	91.3	60	77.9	82	83.7	309	85.4
Total	72		115		77		98		362	

The effectiveness of technical communication was reasonable with 85.1 percent of articles coded as medium or high. Further, the proportion of articles with high effectiveness is increasing with each time period. The effectiveness of management communication is the reverse of technical communication with 85.4 percent of DSS articles coded as low effectiveness. Further, there is no significant improvement in the percentage of "low" articles over time. Unfortunately, only 1.4 percent of articles have high effectiveness in managerial communication.

The picture that emerges in Tables 14 and 15 is a field with a strong technical focus and one whose articles are unlikely to influence managerial activities. Table 15 goes a long way to explain the perceived lack of relevance in DSS (and IS) research. The journals in the sample are quality academic journals. Perhaps the table is a reflection of the nature of these journals, where rigor of the theory base, design, and execution is rewarded by publication. There are no premier professional journals in the sample as the object of this paper was to assess the quality of DSS design-science research. Had, for example, the *Harvard Business Review*, *MIT Sloan Management Review*, and *MIS Quarterly Executive* been in the sample, the statistics for the effectiveness of managerial communication may have been more encouraging. On the other hand, we suspect that the number of DSS articles in these premier professional journals could be small.

4.8. Summary of the HMPR Guideline-Based Analysis

Using the HPMR guidelines provides an evidence-based understanding of the nature of DSS design-science research. Design science is the strategy of 31 percent of published DSS research since 1990. This is consistent with an earlier study by Morrison and George (1995) who found that a similar proportion of MIS research published in *MIS Quarterly* and *Management Science* was design science, although they refered to it as software engineering. DSS design-science research could be the strongest design science tradition in IS research. The focus in DSS design-science research over all time periods has been on instantiations; they constitute close to two-thirds of all research artifacts. Methods comprise around a quarter of DSS design-science artifacts. The "artifact" is the major contribution of most DSS design-science research articles with few making design foundations or methodology contributions. DSS design-science research addresses problems at the lowest level of managerial impact – operational management support is the focus of 75.7 percent of articles. The assessment of relevance shows that two-thirds of articles are of low relevance to IS practitioners, but that the assessment of relevance to managers is significantly better. Evaluation is a major problem area for DSS design-science research with 42.3 percent of articles not undertaking any form of evaluation. Only 13.5 percent of evaluation is performed in the field even though the focus of most articles is an instantiation. The rigor of the theory foundations of DSS design-science research is good, but most articles do not explicitly address research design. In terms of the communication of results, the analysis shows a field with a strong technical focus and one whose research articles are unlikely to influence managerial activities.

5. Strategies for Improving DSS Design-Science Research

DSS design-science research has progressed over the 16 years of the sample period without the assistance of an agreed set of guidelines for what constitutes quality in design-science research or an idea of what is an acceptable design-science research method. The analysis of DSS design-science research using the HMPR Guidelines provides a basis for considering how to improve the quality and impact of DSS design-science research. The discussion on improvement below is organized around four major issues: research method, evaluation, theorizing, and strategic focus. A fifth major issue, relevance, cuts across the first four issues and is discussed throughout this section.

5.1. Research Methods

The first major area of concern is with the research methods of DSS design-science research. This is a surprising concern given the quality of the journals in the sample, and is not explained by an averaging effect where poor results early in the sample are offset by strong results in articles later in the sample. Perhaps the most disappointing result in the literature analysis was that we identified 75 percent of articles as being “weak” with respect to research methods. Most of these articles did not address research design at all. While the rigor of research method was low, the effectiveness of managerial communication (Guideline 7) was also disappointing, with 85 percent of articles coded in the poorest category. Under the analysis of HPMR guideline two, we found 67.7 percent of articles to have low relevance to IS professionals. Combining the results about relevance and communication with the analysis of research methods shows that there has been little trade-off between rigor and relevance in DSS design-science research. Both dimensions of DSS design-science research were scored low, and correlations between all rigor and relevance assessments were virtually zero (with r-squared ranging from 0 to 3 percent). We believe that in design-science research, both rigor and relevance can be high; in an important sense they are related because it is the rigor of academic research that is most valued by practitioners.

A factor that may be working against DSS design-science research and may influence the results of the analysis of research methods and explicit evaluation under the HMPR guidelines is the scale of design-science research projects. A common debate at design-science conferences and workshops is that researchers have great difficulty fitting the reports of their projects into a journal paper. Describing the rationale and nature of an innovative artifact can occupy most of a paper’s space allocation, which leaves little room for research design, evaluation, and analysis discussion. There is no easy solution to this problem. Some have suggested splitting design-science research project outputs over multiple but closely linked articles. Some have suggested the greater use of electronic journals for design-science research as the page limits on individual articles can be relaxed. Case study researchers reported similar issues decades ago when faced with journal page limits conditioned by experimental designs. Design-science researchers should follow their case study colleagues’ lead in crafting significantly tighter articles with sufficient attention to research design and evaluation.

An essential element of improving DSS design-science research is the development, use, and acceptance of research methods that are explicitly grounded as design-oriented research. One impression from coding the 362 articles in the DSS sample is that authors were often trying to fit their design-science research into a framework, even a mindset, that has originated from other research strategies or paradigms. There have been a number of important contributions to IS design-science research methods that can inform a change in design and publishing. March and Smith (1995) proposed “build” and “evaluate” as the two fundamental design-science research processes. All design must produce an innovative artifact, but, as mentioned above, a rigorous evaluation process can elevate a project to design science. Gregg, Kulkarni, and Vinze (2001) developed a design science-style software engineering research methodology (SERM) framework for information systems that comprises three interrelated phases: conceptualisation, formalization, and development. They argued that rigorous design-science research must address at least two of the three phases. Nunamaker et al. (1990/1991) proposed a research method based on systems development. Essentially, their proposal is about design science. Their method involved the processes of constructing a conceptual framework, developing a system architecture, analyzing and designing the system, building a prototype or working system, and observing and evaluating the system. They saw this process as highly iterative. Vaishnavi and Kuechler (2005) proposed a design-science research method, based on the work of Takeda, Veerkamp, Tomiyama, and Yoshikawa (1990) in artificial intelligence, with the major process steps of awareness of problem, suggestion, development, evaluation and conclusion. Arnott (2006) adapted this method for DSS design-science research. The three-cycle approach of Hevner (2007) that frames design-science research in relevance, design, and rigor cycles provides an overall framework for these research methods.

5.2. Evaluation

The quantity and quality of evaluation is the most obvious weakness in DSS design-science research; 42.3 percent of articles in the sample did not undertake any form of evaluation. The presence of rigorous and convincing evaluation is one separator of consulting, professional design, and design-science research. Some form of convincing evaluation should be part of design-science research (Hevner, 2007). This is particularly important if a goal of design-science research is to have practitioners adopt the design artifacts. The rigor that accompanies convincing evaluation is often what separates academic research from vendor presentations and white articles, and it is this rigor that appeals to senior IS professionals. In this sense, rigor equals relevance.

The focus of too many DSS design-science articles is the description of an instantiation without any attempt at evaluation. This is surprising given the quality of the journals in the sample. In the analysis under HPMR guideline three, we suggest that a significant number of DSS researchers may have a computer science or management science background. In these fields, there is arguably less focus on the empirical evaluation of artifacts than in IS design-science research. The analysis in this project shows that those researchers who have performed some form of evaluation usually choose an appropriate strategy but that the quality of the execution of the evaluation needs significant improvement.

We also found that only 13.5 percent of DSS design-science research artifacts are evaluated in the field. This reinforces the perception from the relevance analysis under HPMR guideline two that DSS design-science research is somewhat removed from practice. Confronting significant organization problems in the field is important for high-quality design science. Field-based evaluation should be encouraged in DSS research instead of being the exception. Following the analysis of the sample using the HMPR guidelines, a further coding pass through the sample asked the question “Was the artifact used in actual field environments?”. While use in itself is a long way from evaluation, it does indicate a potential for rigorous fieldwork. This coding pass found that 20.72 percent of articles featured artifacts that were used in actual field environments. Building artifacts and exposing them to the field is a valuable experience for researchers. Design-science research fieldwork can be demanding, messy, and confronting. It is more emotionally demanding than being a non-participant case study observer or from running scenarios in a laboratory environment. In a sense, it requires considerable professional courage from the design-science researcher. On the other hand, challenging a researcher’s propositions in the field can raise the research to a higher level of understanding. DSS as a field is fortunate in that its design artifacts are highly amenable to field work, arguably more so than other branches of IS research.

There is also a need to broaden the base of evaluation methods and techniques. Three methods currently dominate DSS design-science research – simulation, scenarios, and case studies – with experiments also important but much less frequent. This is a narrow methodological base, much narrower than general DSS and IS research. Other evaluation approaches in Hevner et al. (2004, Table 2) may be relevant, and methods that are not in this table should be considered. Action research is one such approach. Another is properly conducted focus groups with senior professionals and managers to gather convincing expert opinion on the effectiveness of an IT artefact (Gibson & Arnott, 2007; Tremblay, Hevner, & Berndt, 2008). Multi-method evaluation is particularly appealing for design-science research, especially the use of a low-cost approach, such as focus groups, to improve an artifact before engaging in a high cost approach, such as a field study.

Finally, the very publication of the HMPR guidelines may improve the level and quality of evaluation in DSS design-science research. Authors will be aware that is now likely that their manuscripts will be in some way held up to the HMPR guidelines. By having evaluation as a prominent guideline, Hevner et al. (2004) have placed the onus on authors to argue why their design artifact works and has value.

5.3. Theorizing

The next major area of DSS design-science research that we believe needs significant attention is the level of theorizing in published articles. This concern is not related to a particular HMPR guideline but emerges from the overall analysis of DSS design science research in this paper. Gregor and Jones (2007) divide design artifacts into material or abstract artifacts. They argue that the abstract artifacts - constructs, models, and methods - are theory or components of theory. One of the strongest findings in the content analysis was that 66 percent of the design artifacts in DSS design-science research are instantiations. The analysis of HPMR guideline four, Research Contribution, showed that only a surprisingly small 2.4 percent of DSS design-science projects have made contributions to the theory-focused areas of design foundations and methodologies. On the other hand, the analysis under HPMR guideline five found that the rigor of the theoretical foundations of articles in the sample was quite sound. This means that they were well founded on what Walls et al. (1992) called kernel theories.

Other researchers (for example, Iivari, 2007; Gregor & Jones, 2007; Venable, 2006) have well canvassed the role of theory in IS design-science research . One aspect of theory that was not explicitly covered by the HMPR guidelines was the nature of design theory in design-science research. Design theory has also been termed “theory for design and action” (Gregor, 2006). A design theory is different to kernel theory or justifactory knowledge, and “shows principles inherent in the design of as IS artefact that accomplishes some end, based on knowledge of both IT and human behaviour” (Gregor & Jones, 2007, p. 322). Iivari (2007, p 49) argues that “without a sound kernel theory it is not justified to speak about ‘design theory’”. Hevner et al. (2004) further argues that a design theory is not essential or needed as an integral component of design-science research. We believe that consideration of how appropriate projects contribute to our general understanding of design theory is important for the development of the field. This is a special case of Hevner et al.’s concept of design-science research projects contributing to the discipline’s “knowledge base”. March and Smith (1995) suggest that researchers should use natural/behavioral science “activities” to theorize about their design-science research and to be able to justify this theory. We noticed that this style of theorizing was not prominent in the DSS sample. Where possible, it is important that researchers identify their contribution to what Iivari (2007) calls prescriptive knowledge, or what Gregor (2006) calls theory for design and action. Although not covered by the HMPR guidelines, we noticed during the coding, principally through the citation of DSS work, that there is little general sense of published research building on previous DSS design-science research projects. Perhaps a cumulative tradition in DSS design-science research will emerge with a greater emphasis on theorizing about design-relevant theory in future research.

5.4. Strategic Focus

If DSS design-science research is going to have a major impact on the way managers and senior professionals work and make decisions, then researchers need to increase the organizational importance of the tasks that are targeted. The analysis under HPMR guideline two, Problem Relevance, showed that 75 percent of DSS design-science research has been focused on operational management problems. Largely driving this statistic is the operational management focus of Personal DSS, a DSS type that comprises 47.2 percent of the DSS design-science research sample. However, we suspect that most PDSS in industry are used to support strategic decision-making. The use of spreadsheets and other modelling software by senior executives can significantly affect organizational strategy, processes, and structures. There were only four strategic PDSS articles in the sample that scored highly on the coding of all seven HMPR guidelines. They were a DSS to help managers evaluate a set of strategic alternatives (Tavana & Banerjee, 1995), an intelligent DSS to support a variety of decisions underlying business acquisitions (Pal & Palmer, 2000), a visualization method for management problems that is demonstrated in a planning task (Zhang, 1998), and a DSS to help decide where to locate installations that process industrial waste (Maniezzo, Mendes, Paruccini, 1998). The ephemeral nature of many strategic PDSS can make their study difficult but has the advantage of shorter engagement times. Nevertheless, DSS design-science research has much to offer this domain and the successful development and evaluation of strategic PDSS artifacts could significantly improve the organizational impact of DSS research. As discussed in Section 5.2, a particularly rewarding approach to increasing strategic focus would be the field use of DSS design-science research artifacts by managers and executives.

Another way to increase the strategic focus of DSS design-science research is to focus on business intelligence applications. The BI movement has raised the visibility of and demand for decision support by senior managers and executives. The Gartner Inc surveys of over 1,000 CIOs since 2007 have found that BI is one of the top technology priorities of CIOs worldwide (Gartner, 2007, 2008, 2009, 2010). Despite this industry prioritization, there is only one paper in the DSS design-science research sample that explicitly addresses BI (Rouibah & Ould-Ali, 2002). Interestingly, this project did address a significant strategic issue. The paper also scored highly in the coding of each HPMR guideline. The lack of BI articles in the sample is not explained by the relative newness of BI as an approach to decision support. BI has been the dominant industry approach to decision support since the late 1990s.

We believe that, in order to increase its organizational relevance and impact, DSS design-science researchers need to embark on BI projects. There is currently an opportunity for IS academics to significantly contribute to BI development. This is because the level of innovation in BI products and methods from major vendors is at an historic low. Because of the commercial importance of BI and DW products, as evidenced by the Gartner surveys mentioned above, major BI vendors have been acquired by large enterprise systems vendors; Business Objects by SAP, Cognos by IBM, and Hyperion by Oracle. A consequence of this merger and acquisition activity is that much of large-scale industry R&D is focused on integrating the major BI tools into the enterprise systems suites, not on fundamental improvements to products and methods. Further, the decision-making focus of BI is being diluted by vendors as they market “operational business intelligence” strategies in order to increase revenues to support acquisitions. This industry situation means that there is an important opportunity for DSS design-science researchers to engage in strategic research that could have a significant impact on organizations. Most of the issues and problems that DSS researchers are interested in can be studied in a BI context. These include governance, sourcing, development methods, visualization and information presentation, Web 2.0 and push technology, and the use of decision theory as a focusing construct. The research strategies, methods, and techniques of PDSS research can be transferred to BI projects (Clark, Jones, & Armstrong, 2007). For example, the framework developed by Eierman, Niederman, and Adams (1995) to provide a general model for personal DSS studies could be used to inform BI research.

6. Concluding Comments

This study shows that design-science research is an important part, perhaps the major part, of DSS research. The lessons learned from the application of the HMPR guidelines should help to significantly improve DSS research. This improvement should come from attention on research method, evaluation, theorizing, and strategic focus. In focusing attention on these areas, care should be taken to maintain the field’s strong performance in the other areas of design-science research. The stakes are high for DSS design-science research. If we get design-science research right, if it is relevant and rigorous, then we will likely have increased influence in industry and the profession, much like the situation in some areas of the medicine discipline. If we get it wrong, the disconnect between academe and practice will be amplified.

While this paper focuses on DSS research, the conclusions may have relevance for IS in general. DSS research comprised 15.1 percent of the articles published in the journals in our sample, which indicates that DSS is a significant proportion of IS research. DSS has a strong IS orientation but also has roots in computer science and management science. These fields have significantly different research traditions, especially with respect to what is regarded as an appropriate design and what level of explicit evaluation is required. As a result, care must be taken in generalizing our results to IS in general. Nevertheless, the call for a greater strategic focus in research, greater rigor in evaluation and research design, and greater attention to theorizing is likely to be highly relevant to IS design-science research.

After coding 362 articles, we can provide an opinion on the effectiveness of using the guidelines in assessing a large sample of design-science research articles. In general, the guidelines were relatively easy to apply to the DSS research. The major difficulty in the content analysis design was the lack of definition of the constructs for some guidelines. We operationalized a number of these opinion-based constructs on three-point scales. This proved to be an effective approach to coding and there were few disagreements between the coders. Two aspects of using the guidelines stand out. First, it was difficult to assess HPMR guideline six, which relates to design as a search process, from the published articles. Second, we believe that HPMR guideline four, which relates to the research contributions of a paper, could be broadened to include a paper's possible contribution of theory for design and action to the "knowledge base" described in Hevner et al. (2004). Notwithstanding these concerns, using the HMPR Guidelines to analyze a large set of DSS design-science research articles did provide a clear idea of the state of the field. More importantly, they provided a clear idea of the areas that need significant improvement.

This study is subject to a number of limitations. The first concerns the representativeness of the sample. The use of the Alavi and Carlson categories as the filter for the DSS design-science research sample could underestimate the sample size because the coding was based on the focus or dominant method of the paper. Some articles that were coded as experiments could have really been design science but the published articles paid cursory attention to artifact construction. In particular, the journal reviewing practices early in the sample could have encouraged this style of write-up. Fortunately, the sample is large and this effect should be diluted. The second major limitation of this research concerns the subjective nature of some of the coding. This is inevitable when interpreting guidelines that do not have well-defined constructs. We believe that researchers with considerable experience in DSS research and design science who used our protocol on our sample would generate similar data.

Our further research into the nature of DSS design-science research includes further development of the "design-science balanced scorecard" mentioned in this paper with the aim of providing a quality measure for individual pieces of design-science research. A second strand of further research will attempt to distil the general design theories that have been used, and should be used, for DSS design-science research.

Acknowledgements

The contribution of each author was equal. We thank the Senior Editor for his insightful comments on early drafts of the manuscript, which significantly improved the paper.

References

Alavi, M., & Carlson, P. (1992). A review of MIS research and disciplinary development. *Journal of Management Information Systems*, *8*(4), 45-62.

Alavi, M., & Joachimsthaler, E. A. (1992). Revisiting DSS implementation research: A meta-analysis of the literature and suggestions for researchers. *MIS Quarterly*, *16*(1), 95-116.

Anthony, R. N. (1965) *Planning and control systems: A framework for analysis*. Cambridge, MA: Harvard University Press.

Arnott, D. (2004). Decision support systems evolution: Framework, case study and research agenda. *European Journal of Information Systems*, *13*(4), 247-259.

Arnott, D. (2006). Cognitive biases and decision support systems development: A design science approach. *Information Systems Journal*, *16*(1), 55-78.

Arnott, D. (2008). Personal decision support systems. In F. Burstein & C. W. Holsapple (Eds.), *Decision support systems handbook* (pp. 127-150). Berlin: Springer-Verlag.

Arnott, D., & Pervan, G. (2005). A critical analysis of decision support systems research. *Journal of Information Technology*, *20*(2), 67-87.

Arnott, D., & Pervan, G. (2008). Eight key issues for the decision support systems discipline. *Decision Support Systems*, *44*(3), 657-672.

Balbo, F., & Pinson, S. (2005). Dynamic modeling of a disturbance in a multi-agent system for traffic regulation. *Decision Support Systems*, *41*(1), 131-146.

Benbasat, I., & Nault, B. (1990). An evaluation of empirical research in managerial support systems. *Decision Support Systems*, *6*(3), 203-226.

Benbasat, I., & Zmud, R. W. (1999). Empirical research in information systems: The question of relevance. *MIS Quarterly*, *23*(1), 3-16.

Burstein, F., & Carlsson, S. A. (2008). Decision Support through Knowledge Management. In F. Burstein & C. W. Holsapple (Eds.), *Decision support systems handbook* (pp. 103-120). Berlin: Springer-Verlag.

Cavaye, A. L. M. (1996). Case study research: A multi-faceted research approach for IS. *Information Systems Journal*, *6*(3), 227-242.

Chen, M. (1995). A model-driven approach to accessing managerial information: The development of a repository-based executive information system. *Journal of Management Information Systems*, *11*(4), 33-63.

Chen, W. S., & Hirschheim, R. (2004). A paradigmatic and methodological examination of information systems research from 1991 to 2001. *Information Systems Journal*, *14*(3), 197-235.

Clark, T. D. Jr., Jones, M.C., & Armstrong, C. P. (2007). The dynamic structure of management support systems: Theory development, research focus, and direction. *MIS Quarterly*, *31*(3), 579-615.

Cooper, B. L., Watson, H.J., Wixom, B.H., & Goodhue, D.L. (2000). Data warehousing supports corporate strategy at first American corporation. *MIS Quarterly*, *24*(4), 547-567.

de Vreede, G.-J., & Dickson, G. (2000). Using GSS to design organizational processes and information systems: An action research study on collaborative business engineering. *Group Decision and Negotiation*, *9*(2), 161-183.

Dennis, A. R., Carte, T. A., & Kelly, G. G. (2003). Breaking the rules: Success and failure in groupware-supported business process reengineering. *Decision Support Systems*, *36*(1), 31-47.

Dennis, A. R., George, J. F., Jessup, L.M., Nunamaker, J. F. Jr., & Vogel, D. R. (1988). Information technology to support group meetings. *MIS Quarterly*, *12*(4), 591-624.

DeSanctis, G., Snyder, J., & Poole, M. S. (1994). The meaning of the interface: A functional and holistic evaluation of a meeting software system. *Decision Support Systems*, *11*, 319-335.

Eierman, M. A., Niederman, F., & Adams, C. (1995). DSS theory: A model of constructs and relationships. *Decision Support Systems*, *14*(1), 1-26.

Eom, S. B. (2007). *The development of decision support systems research: A bibliometric approach*. Lewiston, NY: Edwin Mellen Press.

Eom, H. B., & Lee, S. M. (1990). A survey of decision support system applications (1971-1988). *Interfaces*, *20*(3), 65-79.

Farhoomand, A. F., & Dury, D. H. (1999). A historiographical examination of information systems. *Communications of the AIS*, *1*(19), 1-26.

Fjermestad, J., & Hiltz, S. R. (1998/1999). An assessment of group support systems experiment research: Methodology and results. *Journal of Management Information Systems*, *17*(3), 7-143.
Fjermestad, J., & Hiltz, S. R. (2000/2001). Group support systems: A descriptive evaluation of case and field studies. *Journal of Management Information Systems*, *15*(3), 115-160.
Galliers, R. D., & Meadows, M. (2003). A discipline divided: globalization and parochialism in information systems research. *Communications of the AIS*, *11*, 108-117.
Gartner. (2007). *Creating enterprise leverage: The 2007 CIO agenda (Gartner EXP CIO Report)*. Stamford, CT: Gartner Inc.
Gartner. (2008). *Making the difference: The 2008 CIO agenda (Gartner EXP CIO Report)*. Stamford, CT: Gartner Inc.
Gartner. (2009) *Meeting the challenge: The 2009 CIO agenda (Gartner EXP CIO Report*). Stamford, CT: Gartner Inc.
Gartner. (2010). *Leading in times of transition: The 2010 CIO agenda (Gartner EXP CIO Report)*. Stamford, CT: Gartner Inc.
Gibson, M., & Arnott, D. (2007). The use of focus groups in design science. In *Proceedings of the 18th Australasian Conference on Information Systems (ACIS 2007)*. Toowoomba, Australia: University of Southern Queensland.
Gorry, G. A., & Scott Morton, M. S. (1971). A framework for management information systems. Sloan *Management Review*, *13*(1), 1-22.
Graham, C., Biscotti, F., & Horiuchi, H. (2006). *Forecast: Business intelligence software, worldwide, 2005-2010.* Stamford, CT: Gartner Inc.
Gregg, D. G., Kulkarni, U. R., & Vinze, A. S. (2001). Understanding the philosophical underpinnings of software engineering research in information systems. *Information Systems Frontiers*, *3*(2), 169-183.
Gregor, S. (2006). The nature of theory in information systems. *MIS Quarterly*, *3*(30), 611-642.
Gregor, S., & Jones, D. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems*, *8*(5), 312-335.
Guo, Z., & Sheffield, J. (2008). A paradigmatic and methodological examination of knowledge management research: 2000 to 2004. *Decision Support Systems*, *44*(3), 673-688.
Hall, D., Guo, Y., Davis, R. A., & Cegielski, C. (2005). Extending unbounded systems thinking with agent-oriented modelling: Conceptualizing a multiple perspective decision-making support system. *Decision Support Systems*, *41*(1), 279-295.
Hevner, A. R. (2007). The three cycle view of design science research. *Scandinavian Journal of Information Systems*, *19*(2), 87-92.
Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly*, *28*(1), 75-106.
Hirschheim, R. (1992). Information systems epistemology: An historical perspective. In R. Galliers (Ed.), *Information systems research: Issues, methods and practical guidelines* (pp. 28-60). Oxford: Blackwell Scientific Publications,
Holden, T., & Wilhelmij, P. (1995/1996). Improved decision making through better integration of human resource and business process factors in a hospital situation. *Journal of Management Information Systems*, *12*(3), 21-41.
Huber, G. P. (1984). Issues in the design of group decision support systems. *MIS Quarterly*, *8*(3), 195-204.
Iivari, J. (2007). A paradigmatic analysis of information systems as a design science. *Scandinavian Journal of Information Systems*, *19*(2), 39-64.
Katerattanakul, P., & Han, B. (2003). Are European IS journals under-rated? An answer based on citation analysis. *European Journal of Information Systems*, *12*(1), 60-71.
Kathuria, R., Anandarajan, M., & Igbaria, M. (1999). Linking IT applications with manufacturing strategy: An intelligent decision support system approach. *Decision Sciences*, *30*(4), 959-991.
Keen P. G. W., & Gambino, T. J. (1983). Building a decision support system: The mythical man-month revisited. In J. L. Bennett (Ed.), *Building decision support systems* (pp 133-172). Reading, MA: Addison-Wesley,
Kettelhut, M. C. (1991). Using a DSS to incorporate expert opinion in strategic product development funding decisions. *Information & Management*, *20*(5), 363-371.
Kuula, M. (1998). Solving intra-company conflicts using the RAMONA-interactive negotiation support system. *Group Decision and Negotiation*, *7*(6), 447-464.

Maniezzo, V., Mendes, I., & Paruccini, M. (1998). Decision support for siting problems. *Decision Support Systems*, *23*(3), 273-284.
March, S., & Smith, G. F. (1995). Design and natural science research on information technology. *Decision Support Systems*, *15*(4), 251-266.
Markus, M. L., Majchrzak, A., & Gasser, L. (2002). A design theory for systems that support emergent knowledge processes. *MIS Quarterly*, *26*(3), 179-212.
Meador, C. L., & Ness, D. N. (1974). Decision support systems: An application to corporate planning. *Sloan Management Review*, *15*(2), 51-68.
Moreno-Jiminez, J. M., Joven, J. A., Pirla, A. R., & Lanuza, A. T. (2005). A spreadsheet module for consistent consensus building in AHP decision making. *Group Decision and Negotiation*, *14*, 89-108.
Morrison, J., & George, J. F. (1995). Exploring the software engineering component in MIS research. *Communications of the ACM*, *38*(7), 80-91.
Nelson, R. R., Todd, P. A., & Wixom, B. H. (2005). Antecedents of information and system quality: An empirical examination within the context of data warehousing. *Journal of Management Information Systems*, *21*(4), 199-235.
Neuman, W. L. (2003). *Social research methods: Qualitative and quantitative approaches* (3rd ed.). Boston: Allyn and Bacon.
Noakes, D. J., Fang, L., Hipel, K. W., & Kilgour, D. M. (2005). The pacific salmon treaty: A century of debate and an uncertain future. *Group Decision and Negotiation*, *14*(6), 501-522.
Nunamaker, J. F. Jr., Chen, M., & Purdin, T. D. M. (1990-1991). Systems development in information systems research. *Journal of Management Information Systems*, *7*(3), 89-106.
Orlikowski, W. J., & Iacono, C.S. (2001). Research commentary: Desperately seeking the “IT” in IT research – a call for theorizing the IT artifact. *Information Systems Research*, *12*(2), 121-134.
Osareh, F. (1996). Bibliometrics, citation analysis and co-citation analysis: A Review of literature I. *Libri*, *46*, 149-158.
Pal, K., & Palmer, O. (2000). A decision-support system for business acquisitions. *Decision Support Systems*, *27*(4), 411-429.
Palvia, P., Pinjani, P., & Sibley, E. H. (2007). Editorial: A profile of information systems research published in information & management. *Information & Management*, *44*(1), 1-11.
Pervan, G. P. (1998). A review of research in group support systems: Leaders, approaches and directions. *Decision Support Systems*, *23*(2), 149-159.
Pervan, G. P., & Atkinson, D. J. (1995). GDSS research: An overview and historical analysis. *Group Decision and Negotiation*, *4*(6), 475-485.
Power, D. J. (2008). Decision support systems: An historical overview. In F. Burstein and C. W. Holsapple (Eds.), *Decision support systems handbook* (pp. 121-140). Berlin: Springer-Verlag,
Rangaswamy, A., & Shell, G. R. (1997). Using computers to realize joint gains in negotiations: Toward an “electronic bargaining table”. *Management Science*, *43*(8),1147-1163.
Reico, B., Ibanez, J., Rubio, F., & Criado, J. A. (2005). A decision support system for analysing the impact of water restriction policies. *Decision Support Systems*, *39*, 385-402.
Rouibah, K., & Ould-Ali, S. (2002). PUZZLE: A concept and prototype for linking business intelligence to business strategy. *Journal of Strategic Information Systems*, *11*(2), 133-152.
Sen, R., & Sen, T. K. (2005). A meta-modeling approach to designing e-warehousing systems. *Journal of Organizational Computing and Electronic Commerce*, *15*(4), 295-316.
Simon, H.A. (1996) *Sciences of the Artificial, third edition,* Cambridge, MA: The MIT Press (Original work published 1969).
Stohr, E. A., & Konsynski, B. R. (Eds.). (1992). *Information systems and decision processes*. Los Alamitos, CA: IEEE Computer Society Press.
Takeda, H., Veerkamp, P., Tomiyama, T., & Yoshikawa, H. (1980). Modelling design processes. *AI Magazine, 11*(4), 37-48.
Tavana, M., & Banerjee, S. (1995). Strategic assessment model (SAM): A multiple criteria decision support system for evaluation of strategic alternatives. *Decision Sciences*, *26*(1), 119-143.
Tremblay, M., Hevner, A., & Berndt, D. (2008). The use of focus groups in design science research. In *Proceedings of the Third International Conference on Design Science Research in Information Systems and Technology (DESRIST*), Atlanta, GA.
Turban, E., Aronson, J. E., & Liang, T.-P. (2005). *Decision support systems and intelligent systems* (7th ed.). Upper Saddle River, NJ: Pearson Education.

Vaishnavi, V., & Kuechler, B. (2005). Design research in information systems. Retrieved from http://desrist.org/design-research-in-information-systems.

Venable, J. (2006). The role of theory and theorizing in design science research. In *Proceedings of the First International Conference on Design Science Research in Information Systems and Technology (DESRIST)*. Claremont, CA: Claremont Graduate University.

Walczak, S. (2001). An empirical analysis of data requirements for financial forecasting with neural networks. *Journal of Management Information Systems*, *17*(4), 203-222.

Walls, J. G., Widmeyer, G. R., & El Sawy, O. A. (1992). Building an information systems design theory for vigilant EIS. *Information Systems Research*, *3*(1), 36-59.

Walsham, G. (1995). The emergence of interpretivism in IS research. *Information Systems Research*, *6*(4), 376-394.

Watson, H. J. (2001). Recent developments in data warehousing. *Communications of the AIS*, *8*, 1-25.

Weber, R. P. (1990). *Basic content analysis* (2nd ed.). Newbury Park, CA: Sage.

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS Quarterly*, *26*(2), xiii-xxiii.

Zhang, P. (1998). An image construction method for visualizing managerial data. *Decision Support Systems*, *23*(4), 371-387.

Zhang, P., Sun, J., & Chen, H. (2005). Frame-based argumentation for group decision task generation and identification. *Decision Support Systems*, *39*(4), 643-659.

Appendix A. DSS Design-Science Research Article Coding Protocol

Guideline 1 – The Design Artifact

1.1 Type of Artifact	1 Construct	2 Model	3 Method	4 Instantiation
1.2 What was the artifact?				

Guideline 2 – Problem Relevance

2.1 Importance of business problem	1 Strategic	2 Tactical	3 Operational
2.2 Relevance to IS practitioners	1 High	2 Medium	3 Low
2.3 Relevance to managerial users	1 High	2 Medium	3 Low

Guideline 3 – Design Evaluation

3.1 Type of evaluation

Observational	1 Case study	2 Field study		
Analytical	3 Static	4 Architecture	5 Optimization	6 Dynamic
Experimental	7 Controlled experiment		8 Simulation	
Testing	9 Functional (black box)		10 Structural (white box)	
Descriptive	11 Informed argument		12 Scenarios	13 None

3.2 Choice of evaluation method	1 Highly Appropriate	2 Adequate	3 Poor Choice
3.3 Quality of execution of evaluation	1 High	2 Medium	3 Low

Guideline 4 – Research Contributions

4.1 Contribution Area	1 The design artifact	2 Foundations	3 Design Methodologies

Guideline 5 – Research Rigor

5.1 Theoretical Foundations	1 Strong	2 Adequate	3 Weak
5.2 Research Methodologies	1 Strong	2 Adequate	3 Weak

Guideline 6 – Design as a Search Process

6.1 Decomposition into sub-problems	Yes	No
6.2 Iteration from sub-problem solution to overall problem solution	Yes	No
6.3 Satisficing used to decide on solution convergence point	Yes	No

Guideline 7 – Communication of Research

7.1 Effectiveness of tech-oriented presentation	1 High	2 Medium	3 Low
7.2 Effectiveness of mgt-oriented presentation	1 High	2 Medium	3 Low

8.1 Did the paper mention “design science”?	Yes	No
8.2 If “No”, what did it call it?	or “Nothing”	

9. Design Science Reference Citations

1 March & Smith (1995) DSS
2 Markus et al. (2002) MISQ
3 Nunamaker et al. (1991) JMIS
4 Simon (1996 or earlier) The Sciences of the Artificial
5 Walls et al. (1992) ISR
6 Hevner et al. (2004) MISQ
7 Other:
8 None

10. Free text comments on the paper

About the Authors

David ARNOTT is Emeritus Professor of Information Technology at Monash University, Melbourne, Australia and Director of Monash's Decision Support Systems Laboratory. His principal research area is the development of IT-based systems for managers and executives. He is the author of more than 60 scientific papers in the decision support area, including papers in journals such as the *European Journal of Information Systems*, *Information Systems Journal*, *Decision Support Systems,* and the *Journal of Information Technology*.

Graham PERVAN has over 30 years experience in education, research, and practice in Information Systems and Information Technology (IS/IT). He has published on various IS/IT issues in journals including *Journal of Management Information Systems*, *Information Technology and People*, *Communications of the AIS*, *Decision Support Systems*, *Information and Management*, *International Journal of Medical Informatics*, *Journal of Computer Information Systems*, *Journal of Information Technology* and the *Australasian Journal of Information Systems*.